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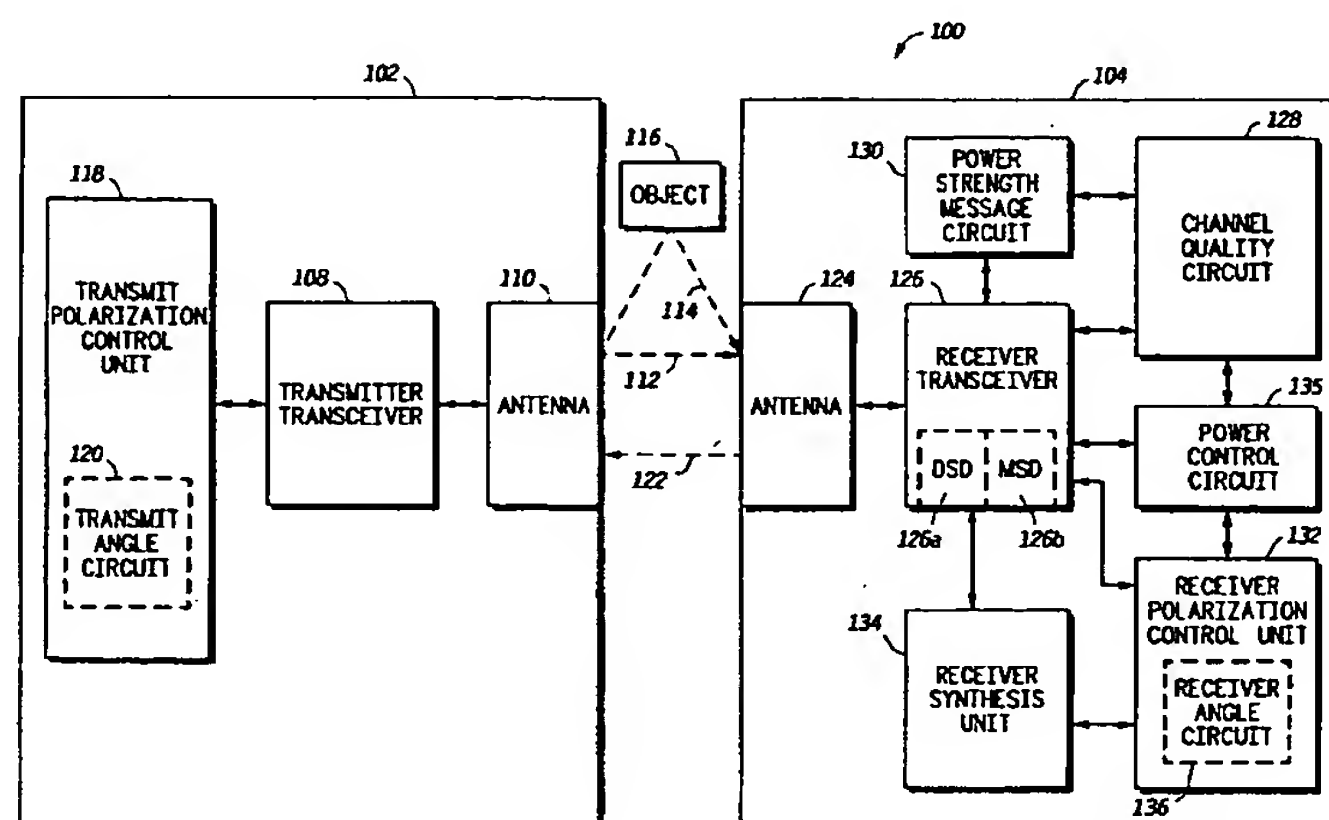(71) Applicant: MOTOROLA INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

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(54) Title: SYSTEM AND METHOD FOR WIRELESS COMMUNICATION USING POLARIZATION DIVERSITY

(57) Abstract: A dynamically controlled polarization diversity system and method (100) for wireless communications comprises a transmitter, such as a base station (102), for transmitting signals with an adaptively controlled polarization state to a receiver, such as a mobile station (104). The polarization state may be adaptively varied by rotating a polarization angle, of the transmit signals. In one version, the polarization angle may be substantially continuously rotated from approximately 180 degrees to approximately 0 degrees in predetermined intervals. As the transmitter transmits signals with a varying polarization state, the receiver analyses the received transmit signals at the various states. The receiver may, for example, detect the received signal strength (RSSI) at each of the polarization states. The receiver then transmits a reply signal to the transmitter indicating the relative RSSI for each of the polarization states. The transmitter thereafter transmits at the polarization state which has the highest RSSI.

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SYSTEM AND METHOD FOR WIRELESS
COMMUNICATION
USING POLARIZATION DIVERSITY

BACKGROUND OF THE INVENTION

The present invention relates generally to wireless telecommunication systems. The invention is especially suited but not limited to providing increased reception quality between a mobile station and at least one base station in a multipath and fading environment.

In a wireless telecommunication system a mobile station, such as a cellular telephone, communicates via radio waves to at least one base station located in a defined geographic cell. Fig. 1 is a graphical representation of a typical wireless telecommunication system comprised of five cell sites 10, 15, 20, 25 and 30. Consistent with current convention, each of the cells 10, 15, 20, 25 and 30 is shown having a hexagonal cell boundary. Within each of the cells 10, 15, 20, 25 and 30 are base stations 35, 40, 45, 50 and 55 that are typically located near the center of its corresponding cell. A mobile station 60 is shown located in the cell 15 and communicating with the base station 40.

If there are no physical objects to block or absorb the radio waves transmitted between the mobile station 60 and the base station 40, the mobile station 60 and the base station 40 communicate to each other by sending signals on a direct signal path, shown as reference numeral 65, directly back and forth.

In practice, however, wireless telecommunication systems frequently operate in areas containing numerous physical objects. Consequently, the

radio waves being transmitted between the mobile station 40 and the base station 60 have the possibility of being partially blocked, absorbed or reflected by some object or feature of the environment. Typically, an environment that blocks, absorbs or generally attenuates radio waves is referred to as a fading environment while an environment that reflects the radio waves is referred to as a multipath environment.

In a fading environment, the radio waves are attenuated in varying ways. The most important environmental attenuation effect is shadowing, where buildings or hills create radio shadows. The problems of shadowing are most severe in heavily built-up urban centers.

In a multipath environment, the radio waves may be reflected from a hill, a building, a truck, an airplane or a discontinuity in the atmosphere. In some cases, the radio waves may be concomitantly reflected and attenuated while in other cases almost all of the radio wave energy is reflected. The effect is to produce many different signal paths between the transmitter and the receiver (whether the transmission is from the base station to the mobile station or vice versa). Fig. 2 graphically shows the situation where the base station 40 communicates with the mobile station 60 via the direct path signal 65 and multipath signals 70 and 72. The multipath signals 70 and 72 are created by the reflection of the transmitted radio waves off of objects 75 and 80. Because the multipath signals 70 and 72 follow several different paths and these paths have different lengths, these multipath signals 70 and 72 arrive at the mobile station 60 at slightly different times. In other words, the different multipath signals 70 and 72 experience different amounts of delay during transmission.

Due to this delay in transmission, the combined signal 65, 70 and 72 is smeared, or spread out, and may experience Rayleigh fading. The effect of multipath propagation is that the reflected radio waves may undergo alteration in some of their fundamental characteristics, particularly phase and amplitude. The phase of a reflected wave may be rotated such that it arrives out of phase

with the direct path signal. If the direct path and multipath signal are exactly 180° out of phase, they will cancel each other out at the receiver and the signal essentially disappears. Other partial out of phase relationships among multiple received signals produce lesser reductions in received signal strength. These

5   reductions in signal strength, or fades, are said to fall within a statistical distribution known as Rayleigh distribution and the phenomenon is referred to as Rayleigh fading. Fig. 3 is a graphical representation of Rayleigh patterns for the received signal strength at the mobile station 60 versus distance. As shown, when the two signals are close to 180° out of phase nulls 85, 90 and 95

10   are produced.

An established countermeasure to Rayleigh fading is the use of diversity. Diversity refers to any of several techniques for sampling the received signal more than once, and, by either combining these sampled signals or selecting the best of them, improving the signal-to-noise (S/N) ratio

15   at the receiver. A variety of diversity enhancing techniques are employed in wireless telecommunication systems to combat signal fading. Due to the limitations in transmission power from battery operated mobile stations, spatial diversity is often used on the reverse link by placing multiple receive antennas at the base station. Other diversity enhancing techniques used on code division

20   multiple access technology (CDMA) forward channels include using rake receivers in the mobile station, orthogonal coding (such as Walsh codes), frequency diversity (such as spread spectrum processing gain), space (such as physically separated antennas), time (such as interleaving and error detection/correction), soft handoff spatial diversity and orthogonal transmit

25   diversity (such as splitting data on odd/even boundaries across transmitters).

In particular, polarized base station transmit antennas may be used to combat deep fades. Unfortunately, a 3 dB loss is incurred by a whip (dipole/mono-pole) antenna at the mobile station receiving the polarized energy in a line of sight path from the base station. To compensate for this

power loss, larger, more powerful base stations are needed and the mobile
station expands a significant amount of power detecting the transmitted signal.
For further discussion of prior polarization techniques, the reader is directed to
U.S. Patent No. 5,724,666 entitled "Polarization Diversity Phase Array

5   Cellular Base Station and Associated Methods" issued on March 3, 1998 to
Dent and U.S. Patent No. 5,691,727 entitled "Adaptive Polarization Diversity
System" issued on November 25, 1997 to Baruch, the disclosures of which are
hereby incorporated by reference.

       Accordingly, there is a need in the art for an improved polarization

10   diversity technique which reduces the aforementioned power loss, which
reduces multipath fading, which substantially reduces frequency selective
fading, which increases the radio link margin, which offers improved diversity
combining, which provides better communication with devices having
arbitrary antenna angles, such as handsets, personal digital assistants (PDAs)

15   and laptops, and which improves battery life by decreasing the power
requirements of the mobile station.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of the invention will become

5   apparent upon reading the following detailed description and upon reference to

the drawings in which:

FIG. 1 is a graphical representation of five exemplary cells within a

wireless telecommunication system, a base station located in one of the cells

and a mobile station located in another of the cells;

10   FIG. 2 is a graphical representation of the base station and mobile

station of FIG. 1 communicating via a direct path signal and two multipath

signals;

FIG. 3 is a graphical representation of Rayleigh patterns for received

signal strength in dBm versus distance for the mobile station shown in FIG. 1;

15   FIG. 4 is block diagram of a communication system in accordance with

the present invention comprising a transmitter, such as the base station of FIG.

1, and a receiver, such as the mobile station of FIG. 1;

FIG. 5 is a schematic diagram in accordance with one version of the

present invention wherein the polarization states for signals transmitted by

20   both the base station and the mobile station, shown in FIG. 4, are adaptively

modified; and

FIG. 6 is a schematic diagram of an antenna system which may be

advantageously used in the base station or the mobile station.

25   # DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One or more specific embodiments of the present invention will be

described below. In an effort to provide a concise description of these

embodiments, not all features of an actual implementation are described in the

specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system related and business related

5   constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

10   In accordance with a version of the present invention, a wireless communication system 100, such as a wireless telecommunication system, is shown in block diagram form in FIG. 4. The communication system 100 incorporates a rotating pilot technique for open and/or closed loop diversity control on a communication channel. In one version of the invention, the

15   communication system 100 preferably adds dynamically optimizing polarization diversity, such as rotating linear polarization diversity, to code division multiple access (CDMA) channels. Preferably, in a cdma200 3G system the linear polarization of an auxiliary pilot channel is dynamically controlled to provide improved communications. As those skilled in the art

20   will readily comprehend, soft-handoff algorithms will need to be adapted if the auxiliary pilot channel is not used.

The structure, control and arrangement of the conventional components and circuits have, for the most part, been illustrated in the drawings by readily understandable block representations and schematic diagrams, which show

25   only those specific details that are pertinent to the present invention. These block representations and schematic diagrams have been employed in order not to obscure the disclosure with structural details which will be readily apparent to those skilled in the art having the benefit of the description herein.

The communication system 100 in FIG. 4 comprises a transmitter 102
which communicates with a receiver 104. The transmitter 102 and the receiver
104 are generic representations of any devices which transmit and/or receive
wireless communication signals. For example and not limitation, the

5   transmitter 102 may be a base station (BTS) or a mobile station (MS). As
those skilled in the art will appreciate the MS may be cellular telephone, a
computer or a personal digital assistant (PDA). The receiver 104 may similarly
be a BTS or MS. Those skilled in the art will readily understand that a single
device may contain the capabilities of both the transmitter 102 and the receiver

10   104. Preferably, the transmitter 102 and the receiver 104 communicate using
wideband CDMA technology.

The transmitter 102 transmits polarized transmit signals via a
transmitter transceiver 108 and an antenna 110. As noted above, the transmit
signals may arrive at the receiver 104 as direct path transmit signals,

15   designated generally by reference numeral 112, and as one or more multipath
transmit signals, designated generally by reference numeral 114. For clarity
and ease of description, the multipath transmit signals 114 are shown being
reflected from only one object 116; however, it should be understood that
multiple objects may be present which reflect multiple multipath transmit

20   signals. A transmit polarization control unit 118 controls the polarization of
the transmit signals 112 and 114. The particular polarization values of the
transmit signals 112, or any other signals in this disclosure, shall be designated
as a polarization state of the signal. For clarity and ease of description the
present invention will be described mainly with respect to adaptively

25   controlling a linear polarization angle of a signal, however, as will be apparent
to those skilled in the art, the invention may adaptively control the polarization
state of the signals.

In particular, a transmit angle circuit 120 in the transmit polarization
control unit 118 controls, or changes, the angle of polarization of the transmit

signals 112 and 114. As will be discussed below, the transmit angle circuit 120 may change the polarization angle of the transmit signals 112 and 114 in any number of manners including in response to feedback from the receiver 104 (closed loop control) or in accordance with a predetermined incremental

5   angle change (open loop control). For CDMA systems, the stepping increments, or intervals, of the polarization angle should be time synchronized (and thus angle step size determined) between the transmitter 102 (or BTS) and the receiver 104 (or MS) with the psuedorandom (PN) code for the transmitter 102. In CDMA systems, the PN code is obtained on the synch channel from

10   the transmitter 102.

The receiver 104 receives the transmit signals 112 and 114 from the transmitter 102 and sends reply signals 122 to the transmitter 102 via an antenna 124 and a receiver transceiver 126. It should be understood that for ease of discussion, the designations transmit signals and reply signals are

15   generic representations of signals sent by the respective transmitter 102 and receiver 104 and the received transmit signals comprise the direct path transmit signals 112 and any received multipath transmit signals 114. The receiver transceiver 126 comprises a direct path signal detector (DSD) 126a for detecting the direct path transmit signal 112 and a multipath signal detector

20   126b for detecting multipath transmit signals 114. A channel quality circuit 128 detects a characteristic of the received transmit signals. For example and not limitation, the channel quality circuit 128 may detect signal strength of the received transmit signal, commonly known as received signal strength (RSSI). Based on the detected RSSI, a power strength message circuit 130 generates

25   power strength measurement messages (PSMMs) which are sent to the transmitter 102 via the reply signals 122.

A receiver polarization control unit 132 controls the polarization state, such as by changing the linear polarization angle, of the reply signals 122. As discussed in more detail below, the present invention adaptively controls and

varies the polarization state of the reply signal to optimize communications between the transmitter 102 and the receiver 104. A receiver synthesis unit 134 synthesizes, or synchronizes, the receiver 104 to the received transmit signals and, in particular, to the changing polarization state of the received

5   transmit signals. The receiver synthesis unit 134 may comprise a digital signal processor (DSP) or a circuit for adjusting amplifier gain and signal phase based on the received transmit signals using known methods.

In response to the receiver synthesis unit 134 and the transmit signals 112 and 114, the receiver polarization control unit 132 controls the

10 polarization angle of the reply signals 122 sent by the receiver 104 to the transmitter 102. A receiver angle circuit 136 may control, or change, the polarization angle of the reply signal 122 in response to the receiver synthesis unit 134 and the received transmit signals. Alternatively, as described below in greater detail with respect to a MS, the receiver 104 may alternatively

15 determine which polarization angle to employ in response to a power control unit 135 or other methods. As is known in the art, the power control unit 135 detects fade situations at the receiver 104 and in response thereto, increases the power of the receiver 104. The polarization angle of the receiver 104 may be rotated, or varied, until a polarization angle is detected which reduces the

20 power.

The present invention is capable of being implemented in a number of versions. In particular, changing the polarization angle on the pilot channel may be performed both in the forward and reverse channels or in either one of the forward or reverse channels. In addition, the closed loop control technique

25 may be implemented in either one or both of the forward and reverse channels. Additionally, the open loop control technique may be implemented in either one or both of the forward and reverse channels. There are a number of configurations which those skilled in the art will readily identify upon reading this disclosure. In a wireless telecommunication system, the BTS and/or the

MS may be configured with or without a polarization diversity enhanced antenna structure. The BTS and/or the MS may be configured with closed loop or open loop polarization diversity control. For example, eight exemplary configurations are set forth below.

5

Configuration Option	Link	Control Loop
1.	Forward Reverse	Not Equipped Open
2.	Forward Reverse	Not Equipped Closed
3.	Forward Reverse	Open Not Equipped
4.	Forward Reverse	Closed Not Equipped
5.	Forward Reverse	Open Open
6.	Forward Reverse	Closed Open
7.	Forward Reverse	Closed Closed
8.	Forward Reverse	Open Closed

For ease of description and clarity the remainder of the disclosure will be directed to a wireless telecommunication system, it should be understood

10   however that the present invention may be advantageously employed in various wireless communication systems and methods. In describing the exemplary

configurations of the present invention, it should be understood that the forward and reverse links can operate independently. Consequently, the description herein will be directed to each of the forward and reverse link in open loop and closed loop operation.

5   In accordance with a version of the present invention, a base station (BTS) 200 and a mobile station (MS) 202 in FIG. 5 are both equipped to dynamically control their respective polarization states, including polarization angles, of transmitted signals. The BTS 200 is shown with a vertical antenna 204 and a horizontal antenna 206 for receiving and transmitting signals. The

10   MS 202 includes an antenna 208 for receiving and transmitting signals. In FIG. 5, signals 210, 212, 214, 216 and 218 are shown for illustrative purposes to depict various signals being transmitted between the BTS 200 and the MS 202. The signals 212, 214 and 216 are multipath signals and are shown reflecting from respective objects 220, 222 and 224. Signals 210 and 218 are

15   direct path signals.

          An BTS angle dial 226 is shown to illustrate the angular rotation of linear polarization of the BTS pilot signal through a transmit angular range, shown as from 180 to 0 degrees. The angular rotation of the linear polarization is preferably some fraction of the BTS PN rate. The angular rotation step, or

20   increment, rate would be based on the specific air interface requirements.

          For illustrative purposes, the BTS angle dial 226 is split into eight partitions of 22.5 degree steps and arrow 228 indicates the rotation of the polarization angle. Such an eight partition division of the linear polarization angle has been shown to be sufficient. If the eight partitions, or 22.5 degree

25   steps, are used and both the BTS 200 and MS 202 have linear polarization diversity antennas, a total of 64 combinations of polarization diversity is possible. Similarly, a MS angle dial 230 divided into 22.5 degree increments is shown representing the rotation, or selection, of a polarization angle for the signals transmitted by the MS 202. A reply angular range is shown, for

example, as being from 0 degrees to 180 degrees. The MS 202 may optionally adjust, or synchronize, the polarization angle for its transmitted signals in accordance with each polarization angle of the BTS 200. However, testing has also shown that rotating both the BTS and MS polarization angles may not always be optimal. Preferably, the MS 202 will detect a maximum RSSI and report the particular polarization angle at which the maximum RSSI occurred to the BTS 200.

For purposes of the following discussion, it is assumed that the receive antennas of the BTS and MS have fixed directivity and gain. In general, only the transmit polarization angle, gain and phase are adjusted since transmit/receive reciprocity can not be guaranteed due to the wide channel separations present in a multipath environment. However, with the benefit of this disclosure, those skilled in the art will be able to readily conceive of a system in which the receive antennas have variable directivity and/or gain.

An exemplary phased array antenna unit 300 which may be advantageously implemented in accordance with the present invention is shown in block diagram form in FIG. 6. The antenna unit 300 consists of two gain blocks 302 and 304 which are responsive to a BTS polarization control unit 306 which operates by adjusting phase and gain. The BTS polarization control unit 306 is responsive to the feedback from the MS. The gain blocks 302 and 304 are used to synthesize the desired polarization angle by changing the phase angle and gain of a particular channel being used to communicate with the MS. For example, if the gain blocks 302 and 304 are at full power and a signal 308 fed into the antenna unit 300 is in phase, a 45 degree (from horizon) linear polarization phasor is synthesized by the antenna unit 300.

Butler matrix combiners 310 and 312 are used to evenly spread energy across linear power amplifiers (LPAs) 314 and 316 and antenna elements 318 and 320. Those skilled in the art will readily understand that the use of the Butler matrix combiner 310 improves the efficiency of the LPAs 312 and 314.

Preferably, antenna elements 318 and 320 have a length substantially equal to ¼ the wavelength of the transmitted signal.

Closed loop operation in the forward link in accordance with a version of the present invention will now be discussed. It should be appreciated that the dynamic polarization diversity of the present invention will reduce fade in the communication link between the BTS 200 and the MS 202 and, concomitantly, reduce the amount of power needed to communicate between the BTS 200 and the MS 202. Accordingly, it is anticipated that the power control of the MS 202 will operate in conjunction with the improved fade reduction.

For purposes of this description, it is assumed that the antenna 208 of the MS 202 does not have a control mechanism and is, for example, a simple whip antenna (possibly with some fixed spatial and fixed polarization diversity) receiving signals in a multipath fading environment. It is also assumed that the MS 202 can make pilot signal strength measurements within a few PN chips in the time domain and within a standard deviation of 1.7 dB. The operation of the closed loop operation will initially be described with respect to IS-95A.

The forward link pilot channel, Walsh code 0, is rotated in predetermined increments, or in a stepped manner, with phase synchronization to the BTS PN sequence. Since the MS 202 is synchronized with the PN sequence of the BTS 200, the MS 202 knows which polarization angle is being transmitted by the pilot of the BTS 200 at a given instant of time. Without resorting to puncturing, the polarization angle of the pilot channel is preferably incremented, or stepped, through some number of divisions between 180 and 0 degrees during the time of one CDMA 20 ms traffic frame.

As the polarization angle is varied, the MS 202 makes power strength measurements at each of the polarization angles. At the completion of a complete frame transmission, the MS 202 is ready to report whether a new and

better transmit polarization angle has been detected. If one has been found, a dim-and-burst type signaling message, such as the aforedescribed reply signal, is preferably transmitted to the BTS 200 indicating the detected better angle. The BTS 200 may then use the information from the MS 202 as feedback into the polarization control unit 118 to control the polarization angle. Alternatively, the BTS 200 may use the information as a new polarization assignment request and adjust its data bearer channel transmissions to the particular MS 202 accordingly.

Forward link open loop operation will next be described in accordance with a version of the present invention. A variety of rotating pilot open loop polarization diversity schemes can be advantageously employed in accordance with the present invention. For example, linear polarization of the data bearer channels may be rotated back and forth in a "windshield wiper" fashion at the fastest possible speed that can be kept in synch with the PN sequence. Such a technique would put individual parts of the CDMA 20 ms frame at different polarization angles which for non-full rate transmissions may eliminate many frame erasures if the commonly used Viterbi algorithm is operating in the MS 202. The technique may help move, or steer, some of the signals out of nulls, thereby reducing the number of chip errors that are sustained. It further allows for more redundancy in the signal which is ultimately fed to a Viterbi decoder. The bits of the transmitted and received signal are interleaved, so that consecutively damaged chips do not necessarily damage consecutive data bits.

Those skilled in the art will readily appreciate that the changes in the polarization angle are not required to be in synch with the PN sequence in such an open loop configuration. If the changes in polarization angle are in synch with the PN sequence, however, a better adaptive response could be obtained in an MS 202 with polarization selective receive antennas. This would tie the best polarization states of spatial fingers of a receive antenna of the MS 202 to the best polarization states of the BTS 200. If the pilot is rotating through a

predetermined discrete set of states on a Poincare sphere on both sides of the transmission link with multiple spatial fingers, there should be obtained an optimal lock in quickly (by searching a smaller space). If the polarization states are simply random, it would not be possible to systematically lock on to the best set of polarization states for the BTS and MS pair.

Reverse link closed loop operation will now be discussed in accordance with another version of the present invention. If the MS 202 is equipped with a linear polarization diversity enhanced antenna, such as is shown in FIG. 6, polarization angle assignments to the MS can be efficiently sent in an adaptive manner in the reverse link via control bits through puncturing. Those skilled in the art will appreciate that this is similar to sending power control bits in IS-95A. The rate of puncture for the polarization angle assignments will likely be less than every 1.25 ms (800 Hz). In an aspect of the present invention, a dim-and-burst type message could be used occasionally to adjust the polarization angle of the MS. In a multipath environment, the reverse and forward channels are widely separated (45 MHz in 2G CDMA), thereby reducing the likelihood of interference from the dim-and-burst type message.

In accordance with another aspect of the present invention, the MS 202 may use its own polarization control unit to decide which polarization angles to employ. One such technique is to respond to a power control unit, or algorithm, in the MS 202. The power control unit in the MS 202 typically recognizes deep fade situations and in response thereto increases the transmit power. Accordingly, the MS 202 may step its transmit antenna off of vertical by 10 degrees and watch for power control bits indicating a reduction in power. If power is increased, the MS could step its transmit antenna back 10 degrees off of vertical the other way (sort of like a windshield wiper). The transmit antenna may then rotate back and forth around the vertical polarization angle until a minimal power output angle is found. By reducing the required power, the battery life in the MS 202 can be extended.

As discussed above, the BTS 200 may rotate the polarization angle through angular intervals, or steps, whose values are determined from the synch channel preferably during registration or origination. Another approach in accordance with an aspect of the present invention is direct assignment of the angular steps. In addition, due to multipath fading, the angles that are optimal may not necessarily the same on each end of the communication link. The information regarding a particular polarization angle may be inserted into repeated voice blocks, punctured in or inserted into dim-and-burst messages.

Reverse link open loop operation will next be described in accordance with a version of the present invention. In accordance with the present invention, open loop polarization diversity may be implemented in the reverse link in a manner similar to that discussed above with respect to the forward link. Those skilled in the art should appreciate however that in CDMA systems spatial diversity is already implemented in the typical reverse link and, therefore, adding polarization diversity in the reverse link would not improve performance to as great of an extent as it will in the forward link.

The present invention may be advantageously employed in the cdma2000 3G air interface which offers enhancements which may be used in accordance with the present invention. For example, the cdma2000 3G air interface supports a coherent MS pilot reverse channel interface providing a continuous radio wave form. In addition, auxiliary pilots, including both auxiliary forward common and dedicated pilots, are supported. Auxiliary common pilots can be added as required. These auxiliary common pilots can either use a traffic channel Walsh code, or, since they are unmodulated with data, they can use longer Walsh sequences. In accordance with the present invention, an auxiliary pilot polarization angle may be rotated.

In a cdma2000 3G system serving a data connection, the BTS may track the auxiliary pilot strength reports from the MSs and may adjust each MS's dedicated control channel and data and voice bearer channel polarization

angles to the best detected angle. The cdma2000 3G air interface also has a dedicated reverse link pilot channel from each MS which may be used in a similar manner with both open and closed loop polarization diversity schemes. For the wideband data transmission case, the polarization diversity schemes may take into account PSMMs of other MSs in an attempt to eliminate interference. Each dedicated channel including those in soft handoff with a plurality of BTSs can be tracking a different polarization angle. Since the dedicated control channels support both 20 ms and 5 ms frames, approximately 10 ms (closed loop) resolution of diversity control may be possible.

The rotation of the polarization angle of the pilot channel in accordance with the present invention is equivalent to discretely stepping around the equator of the known Poincare sphere. A discussion of the Poincare sphere is provided in "Antenna Engineering Handbook - 3rd Edition", by Johnson, Richard C., published by McGraw Hill, 1993. In accordance with the present invention, the BTS, or transmitter, is able to synthesize any polarization state on the Poincare sphere and the MS, or receiver, is able to track a different polarization state with each CDMA finger of its receive antenna. For systems, this must be occuring with respect to the state of each MS being served by the BTS and its near neighbors.

While the invention may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modification, equivalents and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

What is claimed is:

CLAIMS

1.   A method for communicating between a transmitter and a receiver comprising the steps of:

5   transmitting transmit signals having a polarization state from the transmitter;

               receiving the transmit signals at the receiver;

               detecting a characteristic of the received transmit signals at the receiver; and

10   controlling the polarization state of the transmit signals based on the detected characteristic.

2.   The method as recited in claim 21 wherein the transmitter is a base station.

15

3.   The method as recited in claim 22 wherein the receiver is a cellular telephone.

4.   The method as recited in claim 21 wherein the step of controlling the
20   polarization state of the transmit signals comprises the step of rotating a polarization angle of the transmit signals.

5.   The method as recited in claim 24 wherein the step of rotating a polarization angle comprises the step of rotating a linear polarization angle.

25

6.   The method as recited in claim 21 wherein the step of controlling the polarization state comprises the steps of:

               generating a reply signal at the receiver indicative of the detected characteristic;

transmitting the reply signal to the receiver; and

controlling the polarization state of the transmit signals based on the
reply signal.

7.   A base station adapted for wireless communications using code division multiple access channel techniques comprising:

a transceiver for transmitting transmit signals, the transmit signals having a transmit polarization angle; and

a transmit polarization control unit for rotating the transmit polarization angle.

8.   The base station as recited in claim 32 wherein the transmit polarization control unit comprises an transmit angle circuit for rotating the transmit polarization angle between approximately 180 degrees and approximately 0 degrees.

9.   The base station as recited in claim 33 wherein the transmit angle circuit substantially continuously rotates the transmit polarization angle.

10.   The base station as recited in claim 33 wherein the transmit polarization control unit rotates the transmit polarization angle based on quality of the wireless communications.
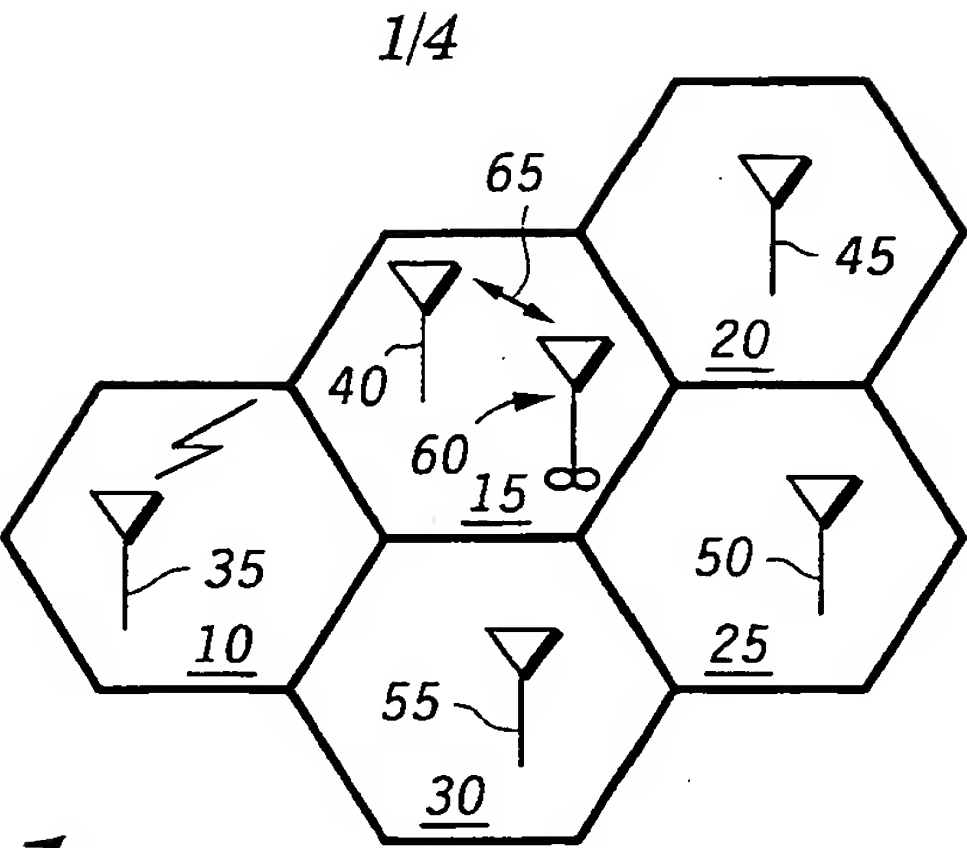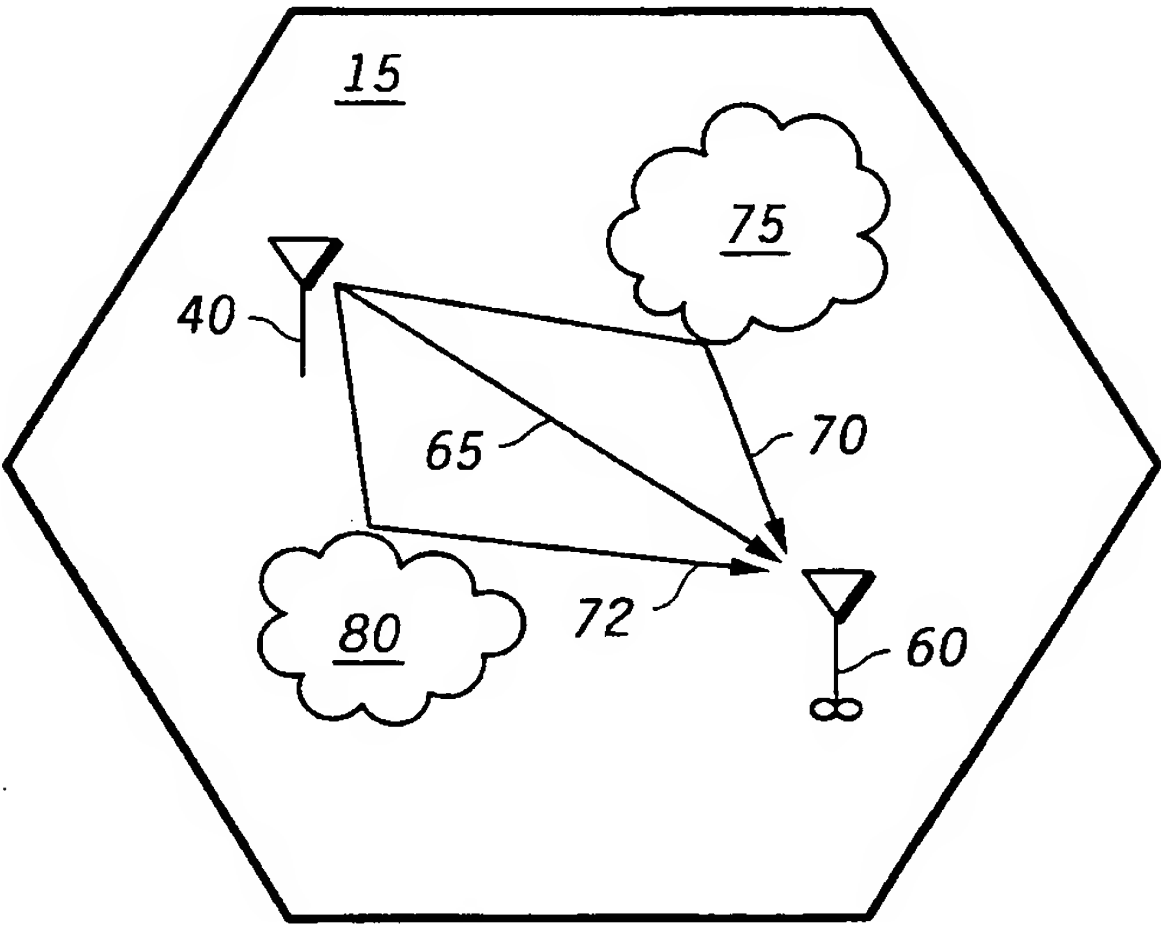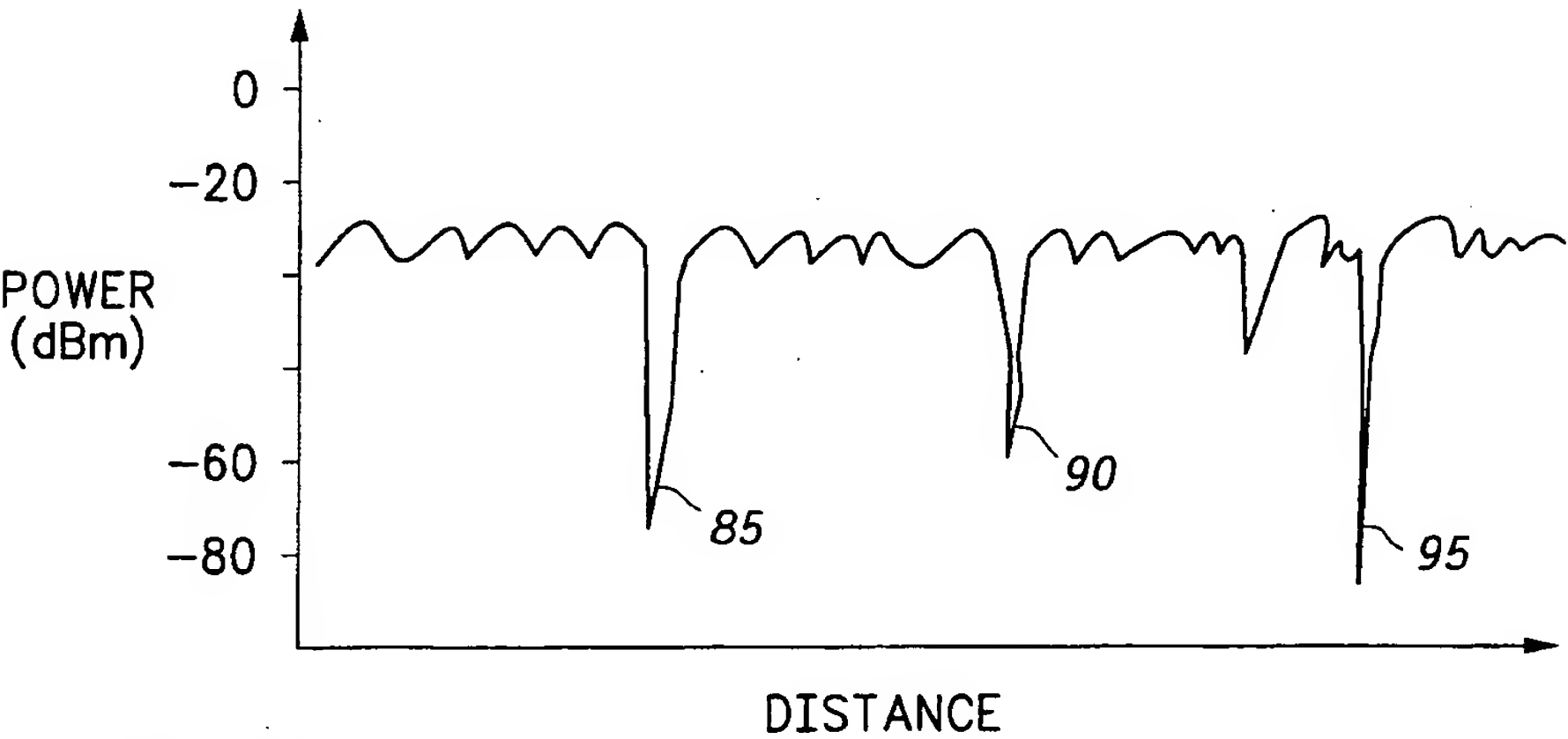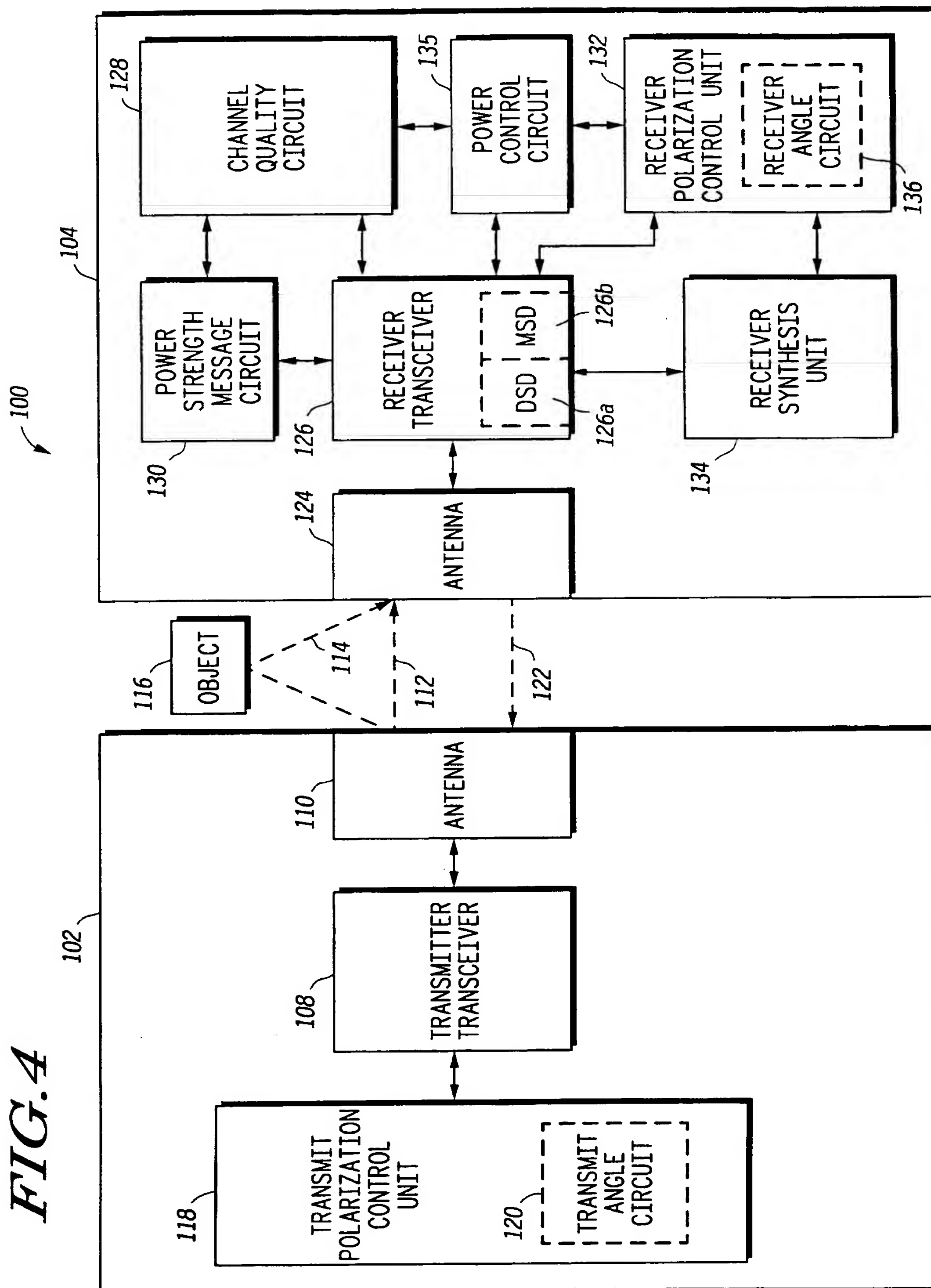
FIG.1

FIG.2

FIG.3

FIG. 4
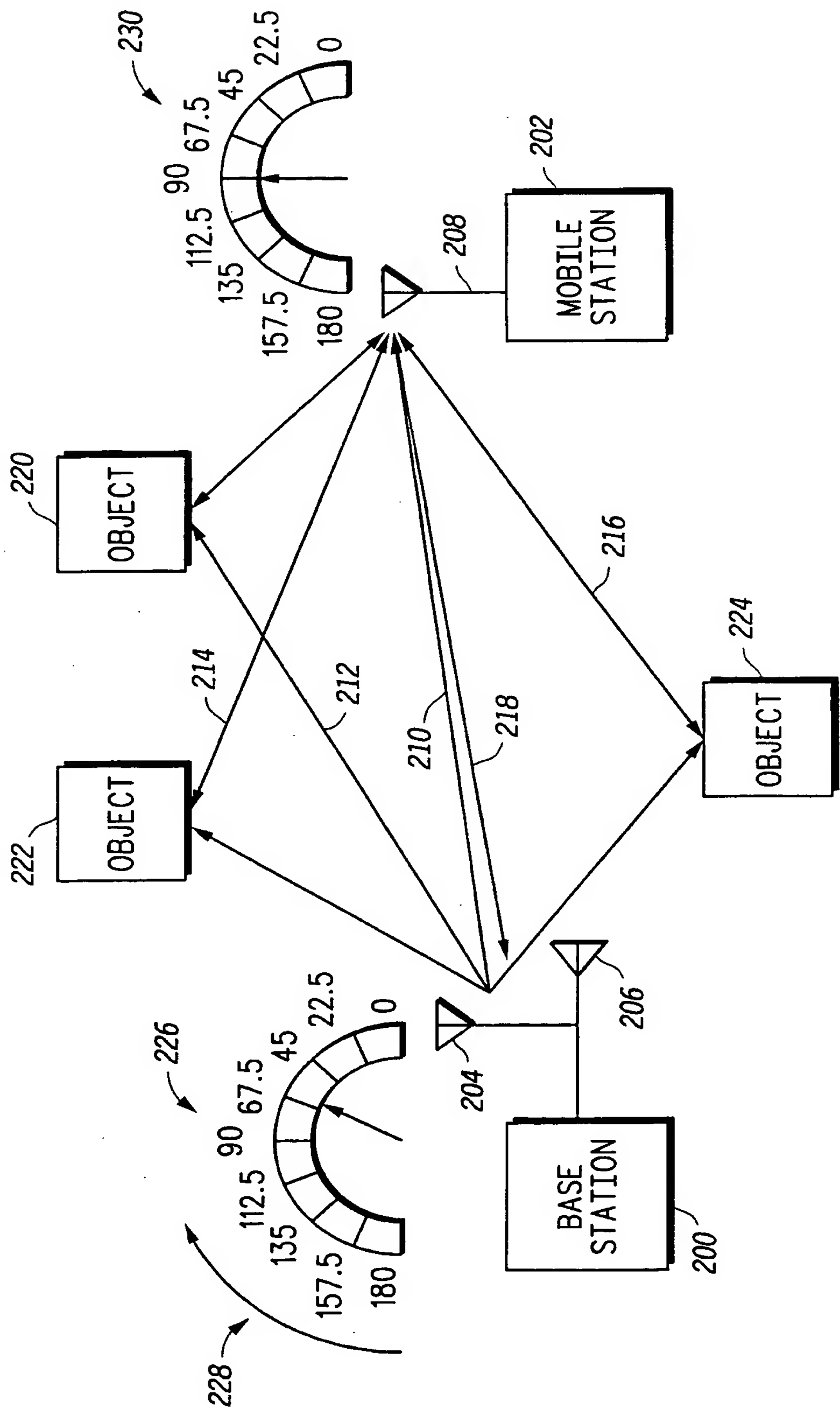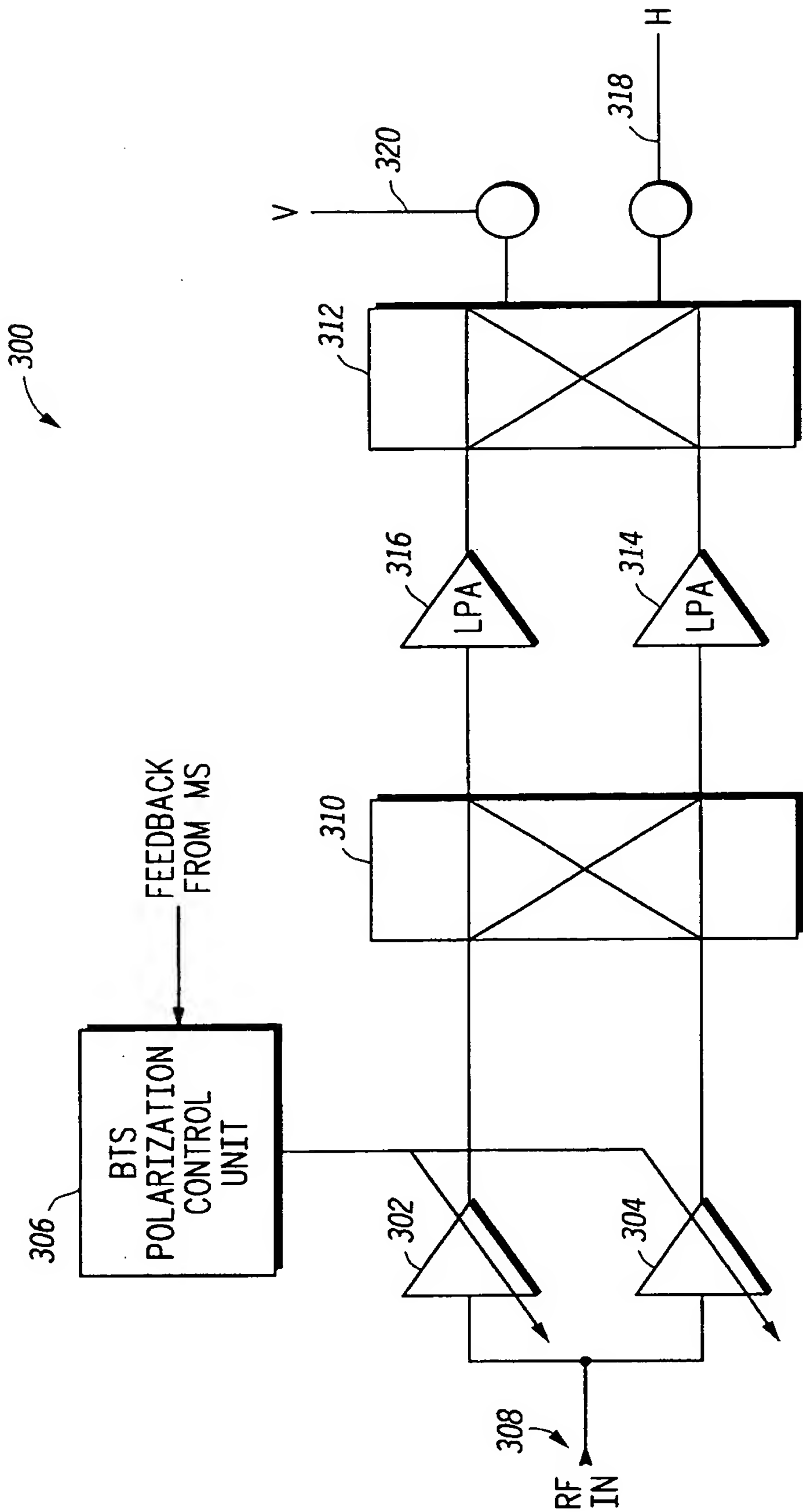
FIG.5

FIG.6

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01Q 21/24; H04B 7/10
US CL : 342/361; 455/522, 69

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 342/361, 365; 455/522, 69

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
EAST - [antenna + polarization + transmitter + receiver + rotat$ near3 angle + (adapt$ or closed adj loop)]

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
IEEE - [polarization + cellular communication], [polarization + communication + rotation]

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,392,459 A (BABA et al) 21 February 1995 (21.02.1995). see Figure 3, spec, 18/19/13.	1-6
Y	US 4,613,990A (HALPERN) 23 September 1986 (23.09.1986) see claim 1, eg.	1-6
Y	US 5,903,238A (SOKAT et al) 11 May 1999 (11.05.1999), see Fig.2 eg. and col. 2, lines 5-25.	1-6
Y	US 4,513,412 A (COX) 23 April 1985 (23.04.85) see Abstract, eg.	1-6
X	SU 4,005,414 A (GOGGINS, Jr.) 25 January 1977 (25.01.1977), see entire document.	7-10
X	US 5,267,268 A (KALLANDER) 30 November 1993 (30.11.1993), see Abstract, eg.	7-10

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2001 (30.01.2001)	**21 JUN 2001**
Name and mailing address of the ISA/US	Authorized officer
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